MASTER OF SCIENCE
IN
MECHANICAL ENGINEERING

OBSTACLE AVOIDANCE CONTROL FOR THE REMUS AUTONOMOUS UNDERWATER VEHICLE

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Future Naval operations necessitate the incorporation of autonomous underwater vehicles into a collaborative network. In future complex missions, a forward look capability will be required to map and avoid obstacles such as sunken ships. This thesis examines obstacle avoidance behaviors using a forward-looking sonar for the autonomous underwater vehicle *REMUS*. Hydrodynamic coefficients are used to develop steering equations that model *REMUS* through a track of specified points similar to a real-world mission track. Control of *REMUS* is accomplished using line of sight and state feedback controllers. A two-dimensional forward-looking sonar model with a 120° horizontal scan and a 110 meter radial range is modeled for obstacle detection. Sonar mappings from geographic range-bearing coordinates are developed for implementation in MATLAB simulations. The product of bearing and range weighting functions form the gain factor for a dynamic obstacle avoidance behavior. The overall vehicle heading error incorporates this obstacle avoidance term to develop a path around detected objects. *REMUS* is a highly responsive vehicle in the model and is capable of avoiding multiple objects in proximity along its track path.

KEYWORDS: *REMUS*, Underwater Vehicle, Obstacle Avoidance, AUV

MOTION ANALYSIS OF A TROLLEY INTERFACE FOR SHIP-TO-SHIP CARGO TRANSFER

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The goal of this thesis is to investigate the effectiveness of a trolley interface for ship-to-ship cargo transfer. The new interface alleviates some of the torsional problems associated with existing ramp designs and can be effectively utilized for both skin-to-skin and Roll-On Roll-Off operations. A mathematical model is developed in order to predict cargo transfer rates in a seaway. Three dimensional hydrodynamic analysis data are used to calculate expected transfer rates in a seaway between a ship and a discharge facility. Results are presented in standard fully developed Pierson Moskowitz sea spectra. It is shown that the new design is a viable alternative to existing methods.

KEYWORDS: Advanced Design Consulting Inc., Hydrodynamic Analysis, Pierson-Moskowitz, Ramp Design, Seabasing, Trolley Interface, WAMIT

TRACKING CONTROL OF AUTONOMOUS UNDERWATER VEHICLES

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Recovery of Autonomous Underwater Vehicles (AUVs) can often be an autonomous operation itself. In the case of an AUV that is launched and recovered at some significant depth below the surface, the recovery platform to which the vehicle will dock is often not a stationary platform. The recovery cage/platform has dynamics associated with it which are induced by wave motion effects on the ship to which the cage is tethered. In order to successfully recover a vehicle into a cage platform it will be preferred for the vehicle to have the capability to compensate for this motion when making its final approach to the cage. Using active compensation, a smaller cage can be utilized for recovery of an AUV. This research attempts to investigate a means by which a vehicle may be made to track, in depth, dynamic motion with zero phase lag between the vehicle and the recovery platform utilizing an error space controller.

KEYWORDS: Underwater Vehicle, AUV, Tracking, Control, Error Space Control, AUV Parameter Identification, AUV Recovery

NONLINEAR DYNAMICS OF CLOSE PROXIMITY SHIP TOWING

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The goal of this study is to investigate the nonlinear dynamics of two ships in close proximity towing. The sway and yaw dynamics of both the leading and the trailing ships were included in the formulation. Previous studies were restricted to a linear analysis, which can accurately predict the regions of stability and instability for the system. The mechanism of loss of stability can be assessed with a systematic nonlinear analysis. The analysis is based on Taylor series expansions of the equations of motion up to third order terms. It is shown that the primary loss of stability occurs in the form of Hopf bifurcations to periodic solutions. A nonlinear stability coefficient was calculated which allows characterization of the stability properties of the resulting limit cycles. The results indicate the effects of ship separation and towing tension on motion stability.

KEYWORDS: Directional Stability, Nonlinear Dynamics, Towing

A NUMERICAL STUDY OF COMBINED CONVECTIVE AND RADIATIVE HEAT TRANSFER IN A ROCKET ENGINE COMBUSTION CHAMBER

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A numerical study was conducted to predict the combined convective and radiative heat transfer rates on the walls of a small aspect ratio cylinder representative of the scaled model of a rocket engine combustion chamber. A high-temperature, high-pressure environment was simulated in the cylinder, with gas velocities at low subsonic levels typical of the conditions leading to the entrance of the nozzle section of a rocket engine. The composition of the gases in the cylinder was determined from the TEP program for the burning of rocket fuel at typical values of the O/F ratio. The thrust of the study was to determine the radiative contribution to the heat transfer rate from the hot participating chamber gases to the cooler wall. The calculations were carried out using the commercial CFD package, CFDACE, and were first benchmarked against known results in the literature for the simpler case of gray chamber walls and a gray participating medium. The non-gray computations were subsequently carried out using gas absorption coefficient values obtained from the exponential wide band model with the help of the fire-modeling program, RADCAL. The effect of different chamber wall temperatures and gas compositions was examined. The main findings of the study are that the radiative contributions at the high gas temperatures being considered are comparable to the convective values, and strongly spectral in nature. Furthermore, this radiative contribution reaches a maximum at a unique optimal optical thickness of the gas that lies within the extremes of the optically thin and thick limiting cases.

KEYWORDS: Radiative Heat Transfer, Rocket Engine, Combustion Chamber, RADCAL, TEP, CFD-ACE, Non-gray Gas, Spectral Transmissivity, Absorption Coefficient